(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
10 September 2004 (10.09.2004)

PCT

(10) International Publication Number
WO 2004/076817 A1

(51) International Patent Classification[7]: E21D 9/06. C09K 7/08

(21) International Application Number: PCT/EP2004/001229

(22) International Filing Date: 10 February 2004 (10.02.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0304602.6 28 February 2003 (28.02.2003) GB

(71) Applicant *(for all designated States except US)*: CONSTRUCTION RESEARCH & TECHNOLOGY GMBH [DE/DE]; Patente, Marken, Dr. Albert-Frank-Strasse 32, 83308 Trostberg (DE).

(72) Inventor; and

(75) Inventor/Applicant *(for US only)*: ELLENBERGER, Peter [CH/CH]; Rebbergstrasse 97, CH-8706 Meilen (CH).

(74) Common Representative: CONSTRUCTION RESEARCH & TECHNOLOGY GMBH; Patente, Marken, Dr. Albert-Frank-Strasse 32, 83308 Trostberg (DE).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 2004/076817 A1

(54) Title: METHOD AND COMPOSITION FOR INJECTION AT A TUNNEL BORING MACHINE

(57) Abstract: A method of boring a tunnel by means of an earth pressure balance tunnel boring machine, comprising the injection at the cutting head of a foamed aqueous solution and an aqueous solution of a water-soluble acrylic acid-based polymer. The method allows easier tunnel boring in soft, sticky soils.

METHOD AND COMPOSITION FOR INJECTION AT A TUNNEL BORING MACHINE

This invention relates to earth pressure balance shield tunnel boring machines and to a composition for use therein.

Tunnel boring machines (TBMs) comprising large diameter cutting heads are well known and widely used. For boring in soft ground, the type usually used is a shield TBM. In this machine, the TBM and its ancillary equipment are housed in a cylindrical body (known as a "shield"). Within the shield, behind the cutting head is a working chamber that receives the excavated soil and a conveyor to convey it away. A further variant of the shield TBM is the earth pressure balance TBM (EPBM). In such a machine, the bored face is maintained by the injection of aqueous foam that both helps maintain the bored face and bear away the soil. The pressure at the face is maintained at a level that will maintain the face, but that will not cause the soil at the surface to rise, with consequent damage to buildings on the surface, hence the name "earth pressure balance". The pressure is controlled by the speed of the TBM, the foam injection rate and pressure as well as by the soil extraction rate by means of the conveyor. In addition, the foams assist in preventing the clogging of the cutting discs, a constant problem in soft soils.

It has now been found that substantially improved performance can be obtained in the use of EPBMs by the injection of an additional substance. The invention therefore provides a method of boring a tunnel by means of an earth pressure balance TBM, comprising the injection at the cutting head of a foamed aqueous solution and an aqueous solution of a water-soluble acrylic acid-based polymer.

The foam may be generated by the foaming of an aqueous solution of at least one surfactant. Any surfactant that can be foamed is suitable for use in this invention, but preferred surfactants include sulphate esters, sulphate ethers and sulphonates.

Preferred examples of suitable surfactant include polyalkylene alkyl ether sulphate, where the polyalkylene oxide chain has an average chain length of from 1-3 alkylene oxide units. If

the surfactant is a lauryl ether sulphate, it is preferred that the ether portion be composed of no more than two oxyethyl units.

Typical commercial materials include the "Alscope" (trade mark) series of Toho Chemical Industry Co.

Other particularly preferred types include monoisopropanol ammonium lauryl alcohol sulphate (commercially available as, for example, "Sulfetal" (trade mark) Cjot 60, α-olefin sulphonate (CAS Registry Number 68439-57-6), commercially available as, for example, "Rhodocal" (trade mark) A-246-L, and C_{8-22} fatty alcohol sulphate salts and C_{8-22} fatty alcohol ether sulphate salts, the fatty alcohol preferably being lauryl alcohol, the ether being an ether formed with a alkylene oxide (preferably ethylene oxide) chain of from 1-3 alkylene oxide units, and the salt-forming cation being preferably selected from alkali metal, magnesium and alkanolamine.

Water-soluble acrylic acid-based polymers are well-known commercial materials. The materials for use in this invention are of relatively low molecular weight, from 2,000 – 20,000, preferably from 2,000 – 10,000 and more preferably from 4,000 – 6,000. Although a small proportion of monomer other than acrylic acid can be tolerated (no more than 10% by weight, it is preferred that the polymer be 100% acrylic acid. The use of the term "acrylic acid" in this invention includes not only the acid itself but also the salts thereof. A preferred acrylic acid is the salt of a monovalent cation such as sodium, potassium, ammonium or a tertiary or quaternary amine.

The acrylic acid-based polymer solution and the foamable surfactant solution may be used as separate solutions, or they may be combined. The invention therefore also provides a foaming solution for use with earth pressure balance tunnel boring machines, comprising an aqueous solution of an acrylic acid-based polymer and an aqueous solution of an anionic surfactant selected from sulphate esters, sulphate ethers and sulphonates.

The surfactant solution may be foamed and injected through the cutting head. The surfactant is preferably injected at a rate of from 0.2-4, more preferably from 0.5-2, most preferably from 0.5-1.5 Kg dry material per M^3 of excavated soil and the acrylic acid-based polymer is injected at a rate of from 0.05 – 2.0, preferably from 0.1 – 1.0, more preferably from 0.2 – 0.5 Kg dry polymer per M^3 of excavated soil.

The method of this invention has a number of advantages over the previous methods utilising foams with EPBMs. The acrylic acid-based polymer has been found to act as a plasticiser for the soil in this situation. This has three important consequences. Firstly, it enables a soil consistency best suited to easy extraction to be more readily achieved. Secondly, this achievement of an optimum soil consistency leads to reduced torque at the cutting head or leads to a higher excavation speed at the defined torque. Thirdly, it permits a reduction in the water needed to plastify the soil. This in turn means that the soil can be more readily disposed of. It is preferred to dispose of soil in landfill, but this is not possible if the water content is too high, as is often the case, forcing either the use of auxiliary dewatering procedures or the use of alternative disposal methods, both more expensive and less convenient.

The invention is further described with reference to the following non-limiting example.

Example

Samples of a standard soil having a spread (according DIN 18555-2) of 120 mm are mixed with 30% FIR (Foam Injection Rate) of foams having a FER (Foam Expansion Rate) of 10. The quantity of foamed liquid used is 30 g per dm^3 of soil.

The foams used are:

a) Foam made from a 3% (wt.) solution of a commercially-available foaming agent (MEYCO® FIX SLF 20);
b) Foam made from a solution containing
3% of MEYCO® FIX SLF 20 and

2% of a 45% solution of a sodium salt of polyacrylic acid, having a weight-average MW of 5000.

	Standard Soil	Standard Soil + Foam a)	Standard Soil + Foam b)
Spread according DIN 18555-2 (mm)	120	170	260

This clearly shows the plastifying effect of the composition used in the present invention. To achieve without foaming compositions the 260mm spread achieved by the composition of the invention, 170 g per dm^3 of soil of extra water was required. In a tunnelling application, the presence of this water would mean either the need for a dewatering procedure before the soil could be used in landfill, or an alternative means of disposal.

Claims:

1. A method of boring a tunnel by means of an earth pressure balance tunnel boring machine, comprising the injection at the cutting head of a foamed aqueous solution and an aqueous solution of a water-soluble acrylic acid-based polymer.

2. A method according to claim 1, in which the aqueous solution for foaming and the aqueous solution of water-soluble acrylic acid-based polymer is added as a single material.

3. A foaming solution for use with earth pressure balance tunnel boring machines, comprising an aqueous solution of an acrylic acid-based polymer and an anionic surfactant selected from sulphate esters, sulphate ethers and sulphonates.

4. A foaming solution according to claim 3, in which the surfactant is a a lauryl ether sulphate, whose ether portion consists of two oxyethyl units maximum.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP2004/001229

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 E21D9/06 C09K7/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 E21D C09K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR 2 690 709 A (SEPPIC SA) 5 November 1993 (1993-11-05) page 3, line 10 - line 14 page 4, line 17 - line 33 page 5, line 7 - line 12 page 5, line 31 - line 35 page 7, line 7 ---	1-4
A	US 5 808 052 A (LANGE WERNER ET AL) 15 September 1998 (1998-09-15) column 4, line 4 - line 15 column 7, line 11 - line 16 ---	1-4
A	WO 01/12952 A (ELLENBERGER PETER ;MBT HOLDING AG (CH)) 22 February 2001 (2001-02-22) page 2, line 23 -page 3, line 10 --- -/--	1-4

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 May 2004	04/06/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Garrido Garcia, M

Form PCT/ISA/210 (second sheet) (January 2004)

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP2004/001229

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 858 928 A (VINCENT MARIE-MADELEINE ET AL) 12 January 1999 (1999-01-12) examples 6,7	1
A	US 6 485 233 B1 (ELLENBERGER PETER) 26 November 2002 (2002-11-26) column 2, line 6 - line 14	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP2004/001229

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
FR 2690709 A	05-11-1993	FR 2690709 A1	05-11-1993
		AT 142743 T	15-09-1996
		AU 4263393 A	29-11-1993
		DE 69304691 D1	17-10-1996
		DE 69304691 T2	13-02-1997
		DK 638137 T3	30-09-1996
		EP 0638137 A1	15-02-1995
		ES 2092307 T3	16-11-1996
		WO 9322538 A1	11-11-1993
		GR 3021184 T3	31-12-1996
		NO 944051 A	27-12-1994
US 5808052 A	15-09-1998	DE 19521693 A1	19-12-1996
		EP 0750027 A1	27-12-1996
		JP 9003451 A	07-01-1997
WO 0112952 A	22-02-2001	AU 6152800 A	13-03-2001
		BR 0013234 A	23-04-2002
		CN 1369033 T	11-09-2002
		WO 0112952 A1	22-02-2001
		EP 1210504 A1	05-06-2002
		JP 2003507604 T	25-02-2003
		TW 477858 B	01-03-2002
US 5858928 A	12-01-1999	FR 2727327 A1	31-05-1996
		FR 2734277 A1	22-11-1996
		FR 2734276 A1	22-11-1996
		FR 2736846 A1	24-01-1997
		AT 199933 T	15-04-2001
		AU 679650 B2	03-07-1997
		AU 3904095 A	06-06-1996
		CA 2163926 A1	29-05-1996
		CN 1132761 A ,B	09-10-1996
		DE 69520407 D1	26-04-2001
		DE 69520407 T2	06-09-2001
		DK 714978 T3	23-04-2001
		EP 0714978 A1	05-06-1996
		ES 2157308 T3	16-08-2001
		FI 955711 A	29-05-1996
		GR 3035854 T3	31-08-2001
		JP 2710100 B2	10-02-1998
		JP 8253691 A	01-10-1996
		KR 189387 B1	01-06-1999
		NO 954800 A	29-05-1996
		PT 714978 T	30-08-2001
		RU 2124046 C1	27-12-1998
		SG 72600 A1	23-05-2000
		TW 419519 B	21-01-2001
		ZA 9510047 A	04-06-1996
US 6485233 B1	26-11-2002	AU 742880 B2	17-01-2002
		AU 9540998 A	27-04-1999
		BR 9812611 A	01-08-2000
		EP 1027528 A1	16-08-2000
		JP 2001519495 T	23-10-2001
		CN 1272901 T	08-11-2000
		WO 9918330 A1	15-04-1999